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ABSTRACT

This is the second of two programmed instruction booklets on the topic of waves, developed by Harvard Project Physics. It covers the relationships among the frequency, period, wavelength, and speed of a periodic wave. For the first booklet in this series, see SE 015 552. (DT)

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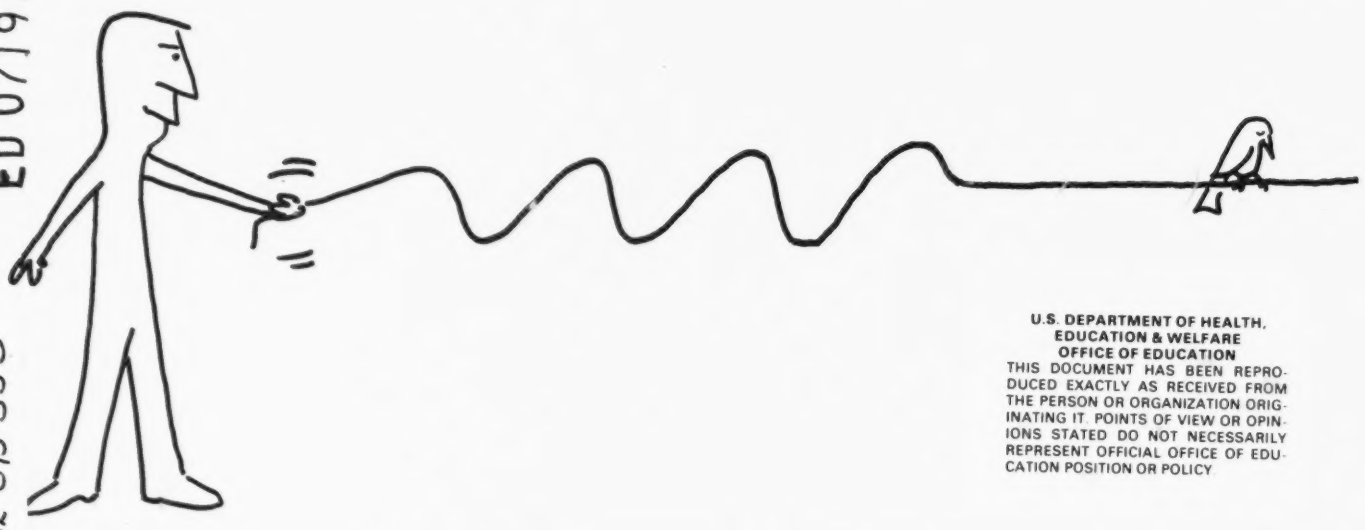
Project Physics **Programmed Instruction**

Waves 2



SE 015 553

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This programmed instruction booklet is the authorized interim version of one of the many instructional materials being developed by Harvard Project Physics, including text units, laboratory experiments, and teacher guides. Its development has profited from the help of many of the colleagues listed at the front of the text units.

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INTRODUCTION

You are about to use a programmed text. You should try to use this booklet where there are no distractions—a quiet classroom or a study area at home, for instance. Do not hesitate to seek help if you do not understand some problem. Programmed texts require your active participation and are designed to challenge you to some degree. Their sole purpose is to teach, not to quiz you.

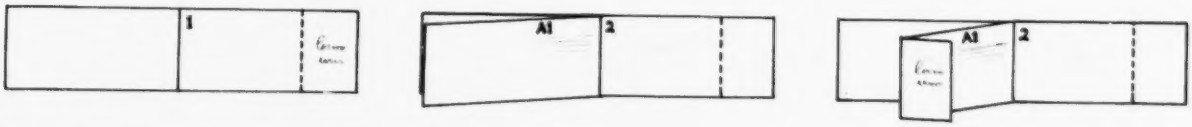
Waves 2 Periodic Waves

When the same wave shape is repeated over and over again, the wave is called a periodic wave. In this program you will learn the relationships among the frequency, period, wavelength, and speed of a periodic wave.

INSTRUCTIONS

1. Frames: Each frame contains a question. Answer the question by writing in the blank space next to the frame. Frames are numbered 1, 2, 3, ...

2. Answer Blocks: To find an answer to a frame, turn the page. Answer blocks are numbered A1, A2, A3, ... This booklet is designed so that you can compare your answer with the given answer by folding back the page, like this:



3. Always write your answer before you look at the given answer.

4. If you get the right answers to the sample questions, you do not have to complete the program.

Sample Question A

The waves on the diagram were produced in 1.5 seconds.

What is the frequency f in cycles per second?

Answer to A

$$\frac{6.0 \text{ cycles}}{1.5 \text{ sec}} = 4.0 \text{ cycles/sec}$$

Sample Question B

The frequency of a wave is the number of (i) _____ that pass a point per (ii) _____, and is equal to the inverse of the (iii) _____ .

Answer to B

(i) cycles
(complete waves)

(ii) second

(iii) period

Sample Question C

If waves of frequency $f = 20$ cycles per second travel in a medium with speed $v = 40$ meters per second,

(i) what is the wavelength of the waves in the medium?

(ii) what is the period of the waves?

Answer to C

(i) $\lambda = \frac{v}{f}$

$= \frac{40 \text{ m/sec}}{20 \text{ cycles/sec}}$

$\lambda = 2.0 \text{ m/cycle}$

(ii) $T = \frac{1}{f} = \frac{1}{20} \text{ sec/cycle}$

$T = .05 \text{ sec/cycle}$

Sample Question D

The figure shows an attenuated (damped) periodic wave.

Of the following, which property is changing?

speed of the wave, wavelength, amplitude, frequency, period

Answer to D

Only amplitude is changing.

If you were able to answer the sample questions correctly, the rest of the program is optional.

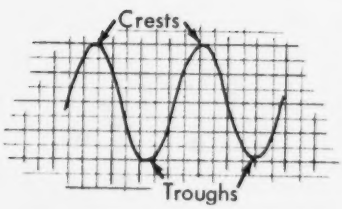
1

Waves are shaken on a rope by moving point P up and down.

Crests are generated when the displacement of P is positive, and troughs are made by negative displacements of P.

Label the crests and troughs on the diagram.

A1

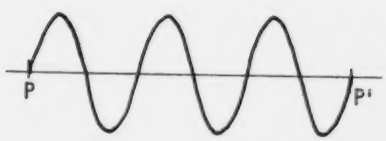


2

A complete waveform is a cycle.

Draw 3 cycles between points P and P'.

A2

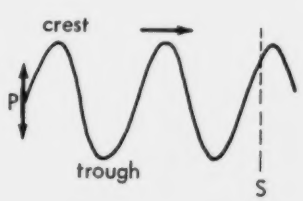


3

In one second, point P makes 6 cycles, and each cycle contains a crest and a trough.

(i) How many cycles per second pass an observer at point S?

(ii) How many troughs pass the observer at S in one second?



A3

(i) 6 cycles

(ii) 6 troughs

4

The number of cycles per second is the frequency of the wave. (In the last question, the frequency was 6 cycles per second.)

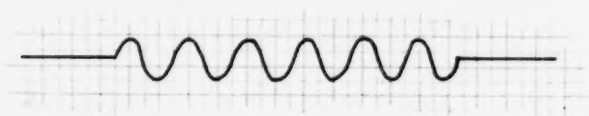
If 12 cycles are produced in 3.0 seconds, the frequency of the waves is _____ _____.
(units)

A4

$$f = \frac{12 \text{ cy}}{3.0 \text{ sec}} = 4.0 \text{ cycles/sec}$$

5

The waves on the diagram were produced in 1.5 seconds.



What is the frequency f in cycles per second?

A5

$$\frac{6 \text{ cycles}}{1.5 \text{ sec}} = 4.0 \text{ cycles/sec}$$

6

The quantity T represents the time required to generate one cycle (complete wave). The time interval (T) is called the period of the wave.

When f = 1 cycle/sec ; T = 1 sec/cycle

f = 2 cycles/sec ; T = 1/2 sec/cycle

f = 3 cycles/sec ; T = 1/3 sec/cycle

In general:

f = x cycles/sec ; T = _____ .

A6

$T = \frac{1}{x}$ sec/cycle.

7

From frame 6 we see that the period is related to the frequency of a wave.

$T = \frac{1}{f}$, and $f = \frac{1}{T}$.

What is the period of a wave whose frequency is 10 cycles/sec?

A7

$$T = \frac{1}{f}$$

$$= \frac{1}{10} \text{ sec/cycle}$$

$$= 0.1 \text{ sec/cycle}$$

8

The frequency of a wave is the number of (i) _____ that pass a point per (ii) _____ , and is equal to the inverse of the (iii) _____ .

A8

(i) cycles

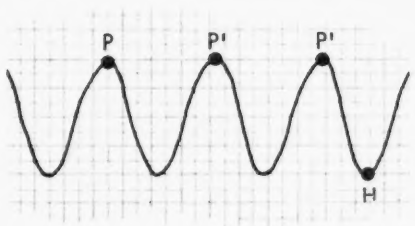
(ii) second

(iii) period

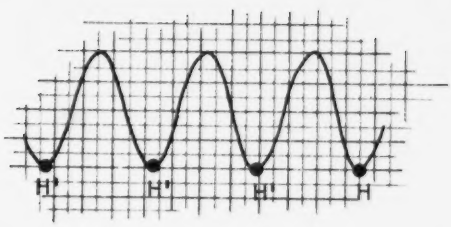
9

Points marked P' on the diagram correspond to the point P because they are in the same part of a complete cycle.

On the diagram, mark points H' that correspond to the point H.

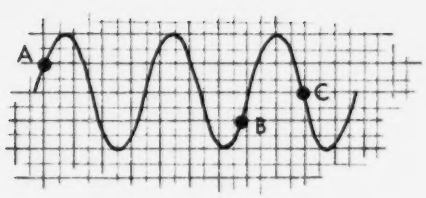


A9

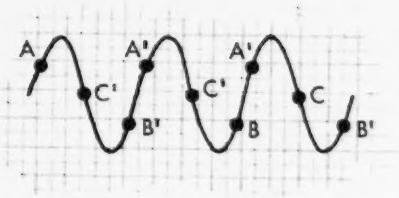


10

On the wave diagram, mark as A', B' and C' all points which correspond respectively to points marked A, B and C.



A10

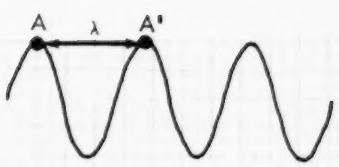


11

The Greek letter lambda (λ) is used to represent wavelength.

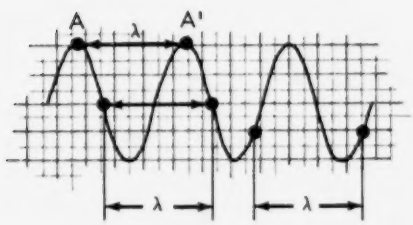
The wavelength is the distance between corresponding points of adjacent cycles. Points A and A' are examples.

On the diagram mark other pairs of points whose separation is λ.



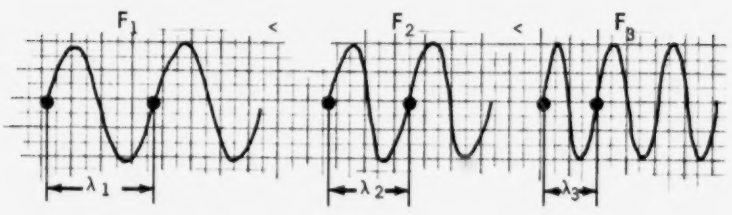
A11

some possible solutions:



12

Higher frequencies in the same medium produce shorter wavelengths.



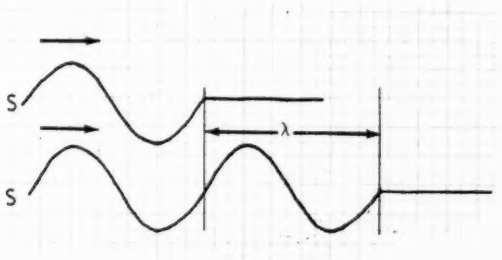
Mathematically speaking, the wavelength and frequency are _____ proportional.

A12

inversely

13

The top diagram shows a wave moving away from source s, and the bottom diagram shows the wave one complete cycle later.



During the time interval from one diagram to the other, the elapsed time is equal to the (i)_____ of the wave, and the wave had moved a distance of (ii)_____.

A13

(i) period (T)

(ii) one wavelength (λ)

14

If a wave moves one wavelength λ in one period of time T, wave speed can be calculated.

$$v \text{ (wave speed)} = \frac{\text{distance}}{\text{time}} = \frac{\lambda}{T}$$

Find the speed of a wave whose wavelength λ is 1.5 cm, and whose period T is 0.1 seconds.

A14

$$v = \frac{\lambda}{T}$$

$\lambda = 1.5$ cm

$T = 0.1$ sec

$$v = \frac{1.5 \text{ cm}}{0.1 \text{ sec}}$$

$= 15$ cm/sec

15

Recall that $f = \frac{1}{T}$ (frame 7) and $v = \frac{\lambda}{T}$ (frame 14).

What is the speed of a wave written in terms of wavelength λ and frequency f?

A15

$v = f\lambda$

16

If waves of frequency $f = 20$ cycles per second travel in a particular medium with speed $v = 40$ meters per second,

(i) what is the wavelength of the waves in the medium?

(ii) what is the period of the waves?

A16

(i) $\lambda = \frac{v}{f}$

$= \frac{40 \text{ m/sec}}{20 \text{ cycles/sec}}$

$\lambda = 2.0 \text{ m/cycle}$

(ii) $T = \frac{1}{f} = \frac{1}{20}$

$T = .05 \text{ sec (per cycle)}$

17

Actually, it is very difficult to produce a perfectly periodic wave. One reason is the dissipation of energy which causes waves to be "damped" or "attenuated."

The figure shows an attenuated (damped) periodic wave.

Of the following, which property is changing?

speed of the wave, wavelength, amplitude, frequency, period

A17

Only amplitude is changing.